Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Project Overview and Fall 2006 Results

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California Air Resources Board – ZEV Technology Symposium
September 25, 2006

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Outline

- Project Objectives and Overview
- Industry Partners; H2 vehicles and stations
- Process and Methodology for Making Results Public
- Key Fall 2006 Results
  - Vehicles
    - Net fuel cell system efficiency
    - Fuel economy and range
    - Safety
  - H2 Refueling Infrastructure
    - Refueling Rates
    - Safety
    - H2 station purity and impurities
    - Maintenance
  - High-level project status metrics
- Summary and Future Results

Project Objectives and Targets

- Objectives
  - Validate H_2 FC Vehicles and Infrastructure in Parallel
  - Identify Current Status of Technology and its Evolution
  - Assess Progress Toward Technology Readiness
  - Re-Focus H_2 Research and Development

Hydrogen refueling station, Chino, CA Photo: NREL

Key Targets

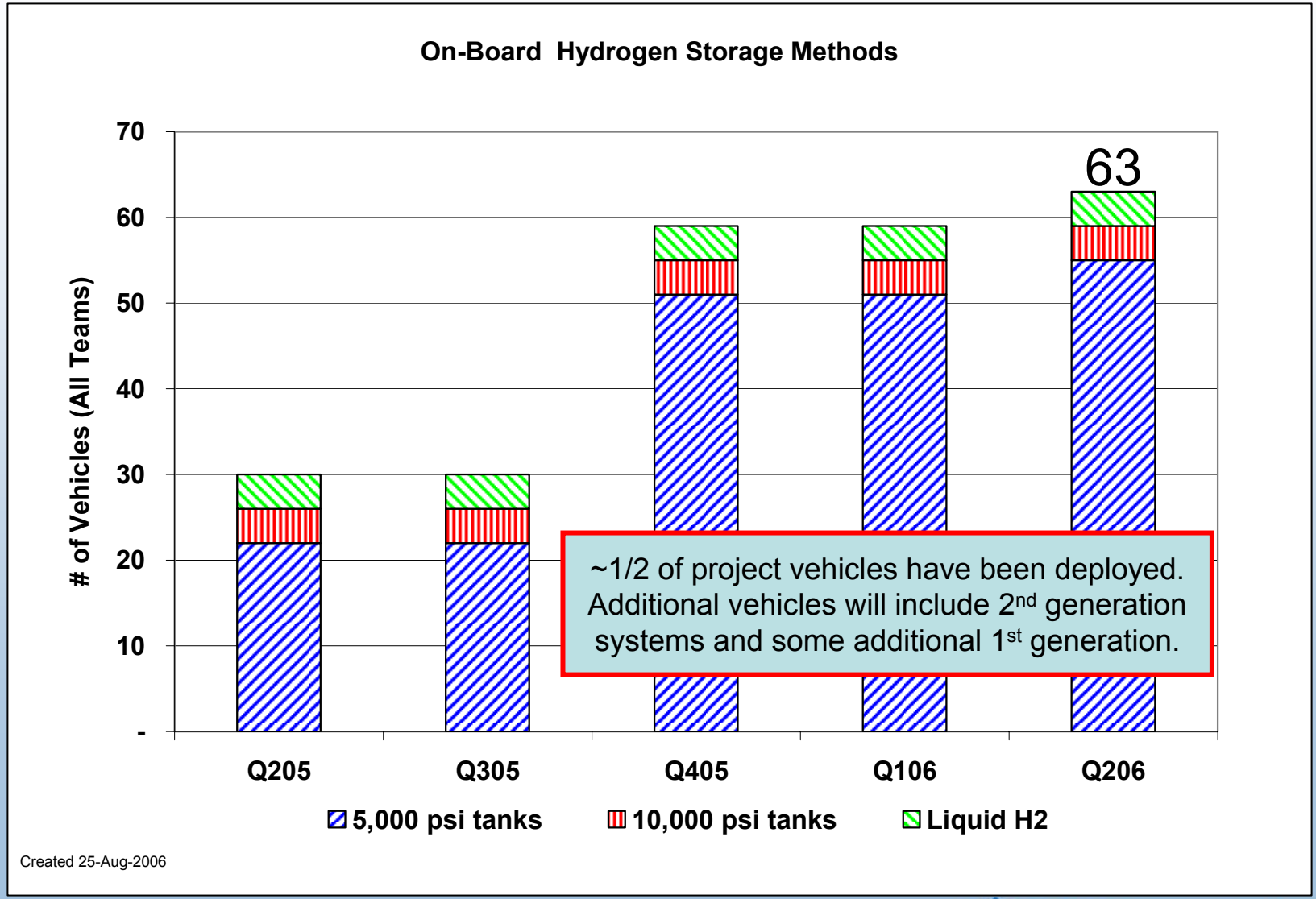
Performance Measure	2009*	2015**
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station	$3/gge	$2-3/gge

* To verify progress toward 2015 targets
** Subsequent projects to validate 2015 targets

Teams are Fielding Four Main Types of Vehicles

Validation also includes FCV Sprinter vans

Number of Learning Demo Vehicles in Operation
H2 Storage Technologies Used



Representative Hydrogen Refueling Infrastructure Supporting Vehicles

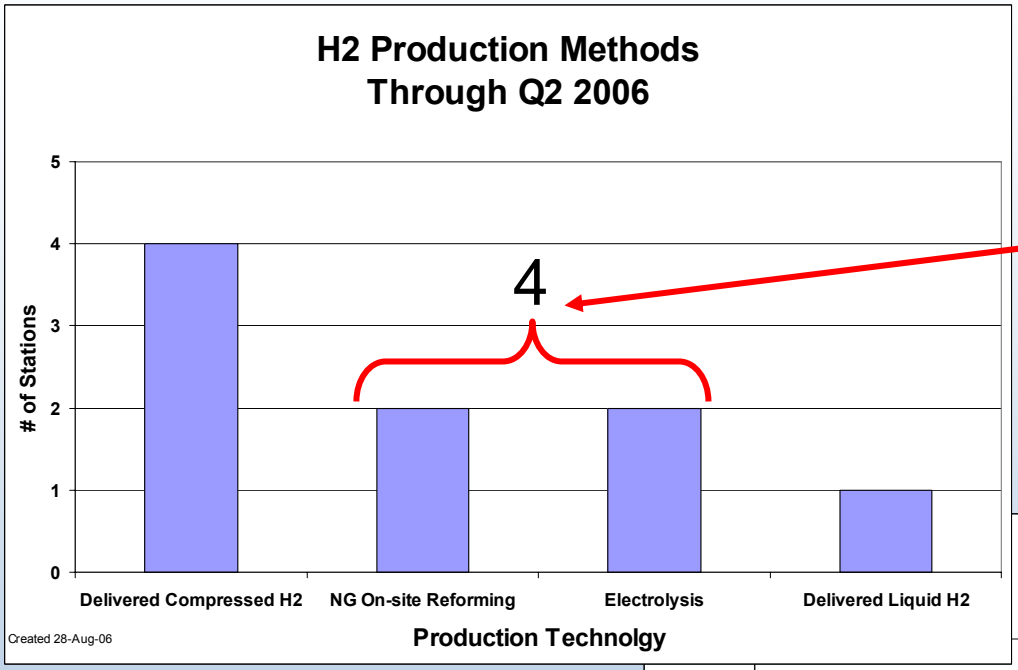
DTE/BP Power Park, Southfield, MI

LAX refueling station

Hydrogen and gasoline station, WA DC

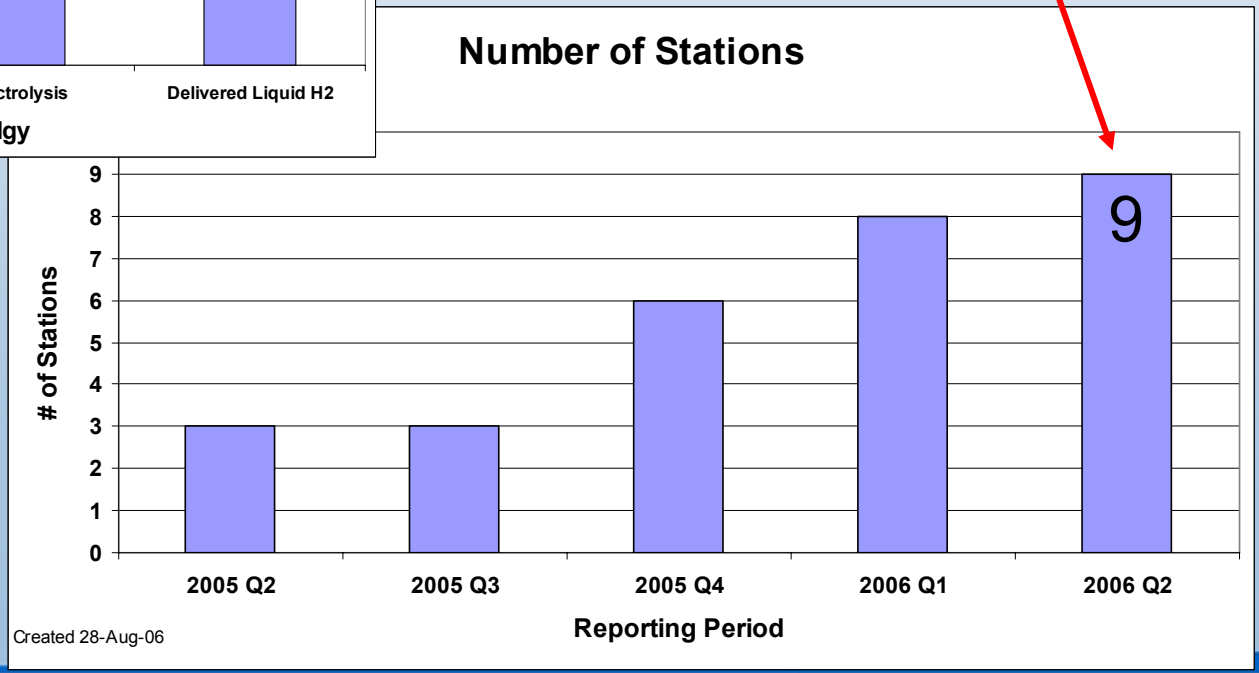
Chino, CA

Number and Type of Learning Demo Hydrogen Refueling Stations Online

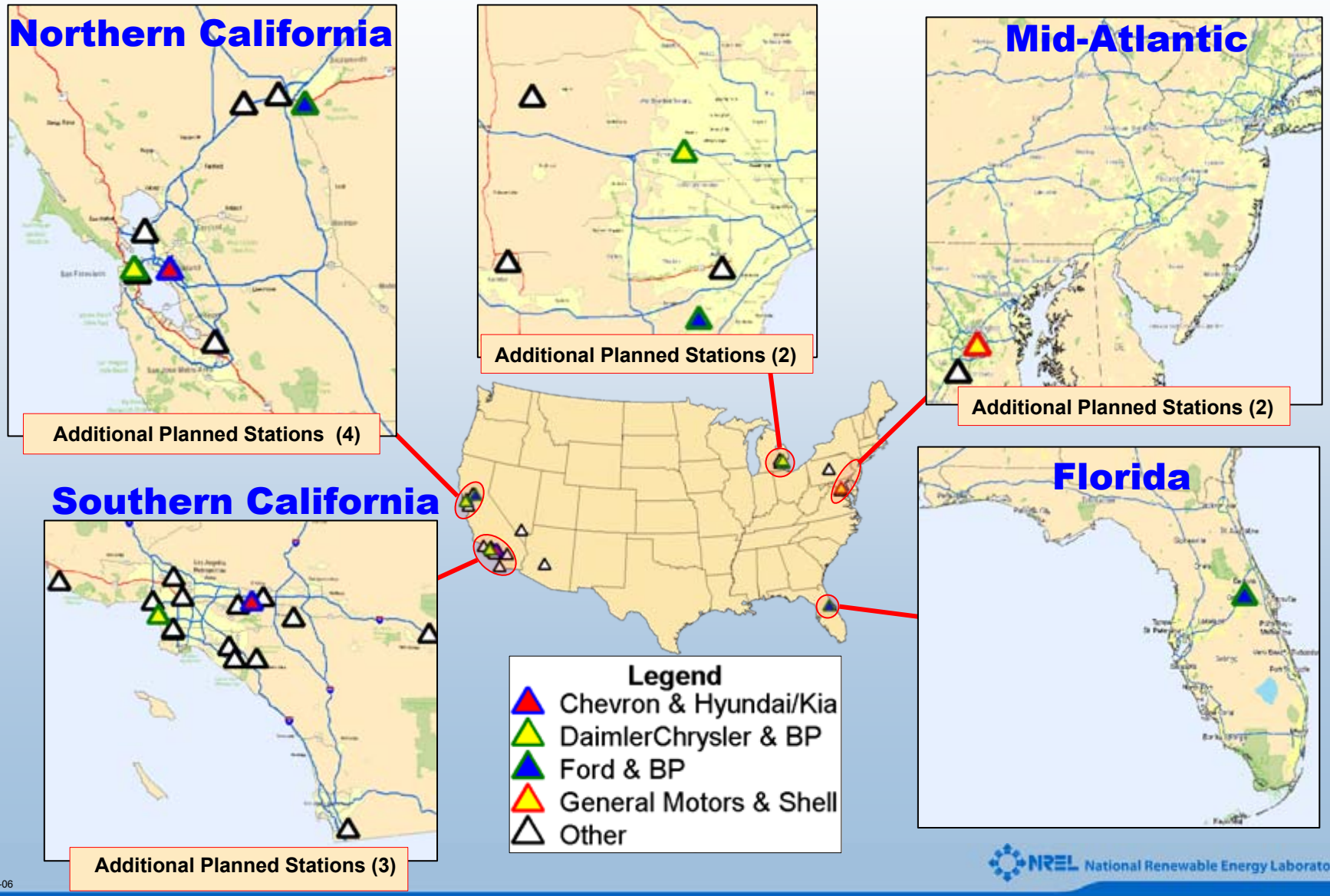


~1/2 of stations are producing H2 on-site

~1/2 of 20 planned refueling stations are online



Refueling Stations from All Four Teams Test Vehicle/Infrastructure Performance in Various Climates



Providing Data Analysis and Results for Both the Public and for the Industry Project Teams

Raw Data, Reports

Data is delivered to NREL's Hydrogen Secure Data Center (HSDC) on CD/DVDs

Hydrogen Secure Data Center (HSDC)

- Located at NREL: Strictly Controlled Access
- Detailed Analyses, Data Products, Internal Reports

Data protected in HSDC for 5 years after data is developed under EPACT 2005, Sec. 810

Composite Data Products

- Pre-agreed upon aggregate data results for public
- No confidential information

Detailed Data Products

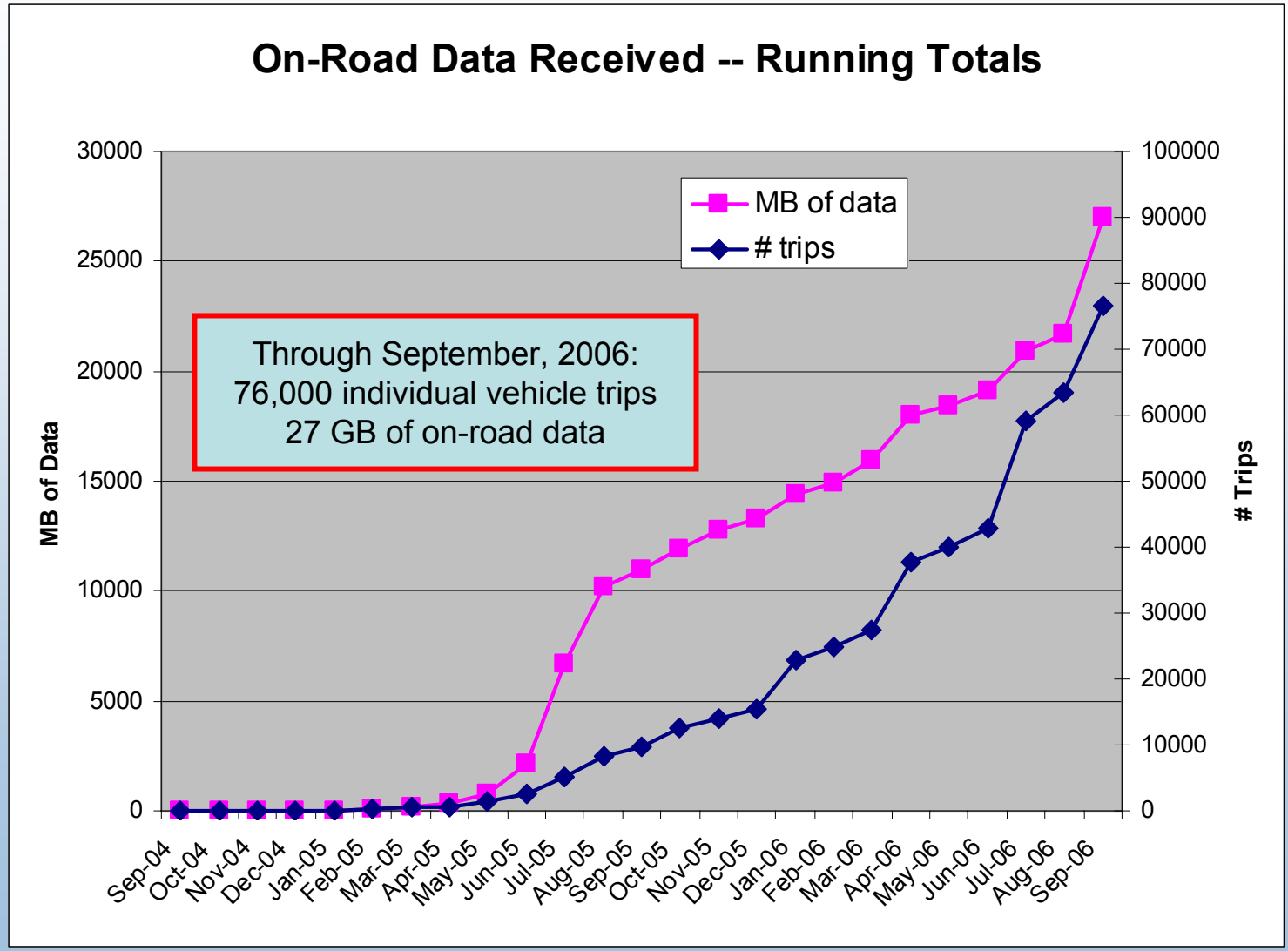
- Only shared with company which originated the data

Key Vehicle and Infrastructure Data Collected

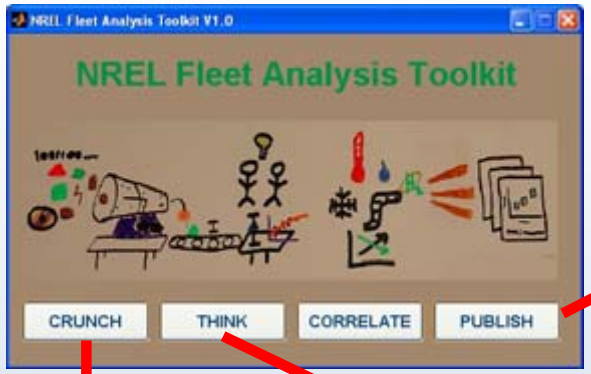
Key Vehicle Data	Key Infrastructure Data
Stack Durability	Conversion Method
Fuel Economy (Dyno & On-Road) and Vehicle Range	Production Emissions
Fuel Cell System Efficiency	Maintenance, Safety Events
Maintenance, Safety Events	Hydrogen Purity/Impurities
Top Speed, Accel., Grade	Refueling Events, Rates
Max Pwr & Time at 40C	H_2 Production Cost
Freeze Start Ability (Time, Energy)	Conversion, Compression, Storage, and Dispensing Efficiency
Continuous Voltage and Current (or Power) from Fuel Cell Stack, Motor/Generator, Battery & Key Auxiliaries: (Dyno & On-Road)	

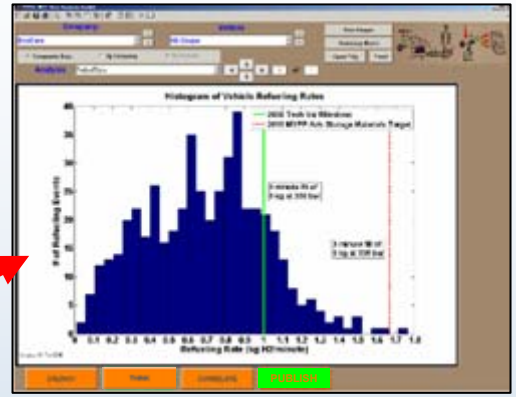
Five Quarters of Data Analyzed

Current Status of Data Reporting to the Hydrogen Secure Data Center at NREL

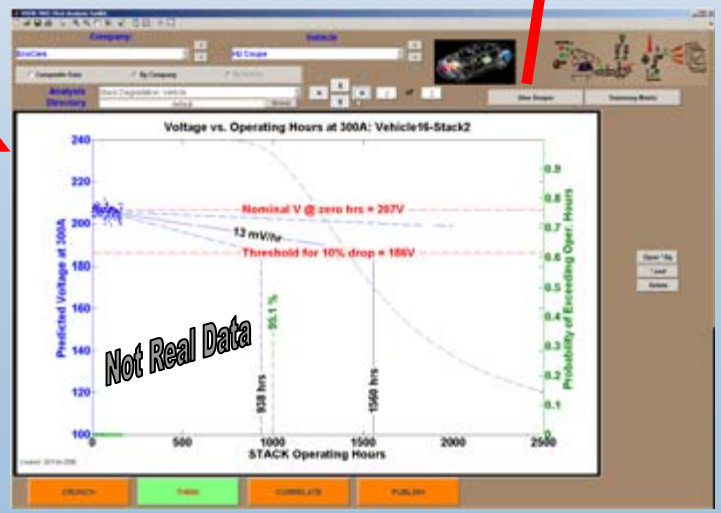


Analysis Calculations and Results are from NREL-Developed GUI – Fleet Analysis Toolkit (FAT)



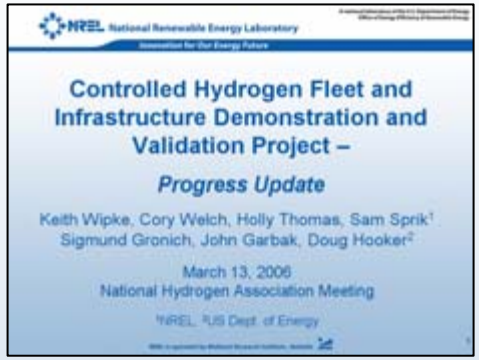


TripView



After Industry and DOE Review, Composite Data Products are Published in Hydrogen/Vehicle Conferences

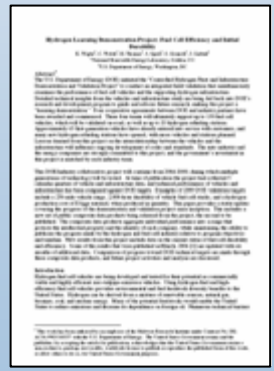
Spring 2006



National Hydrogen Association Conference
March 13, 2006

Fall 2006

EVS-22 Conference
October 26, 2006



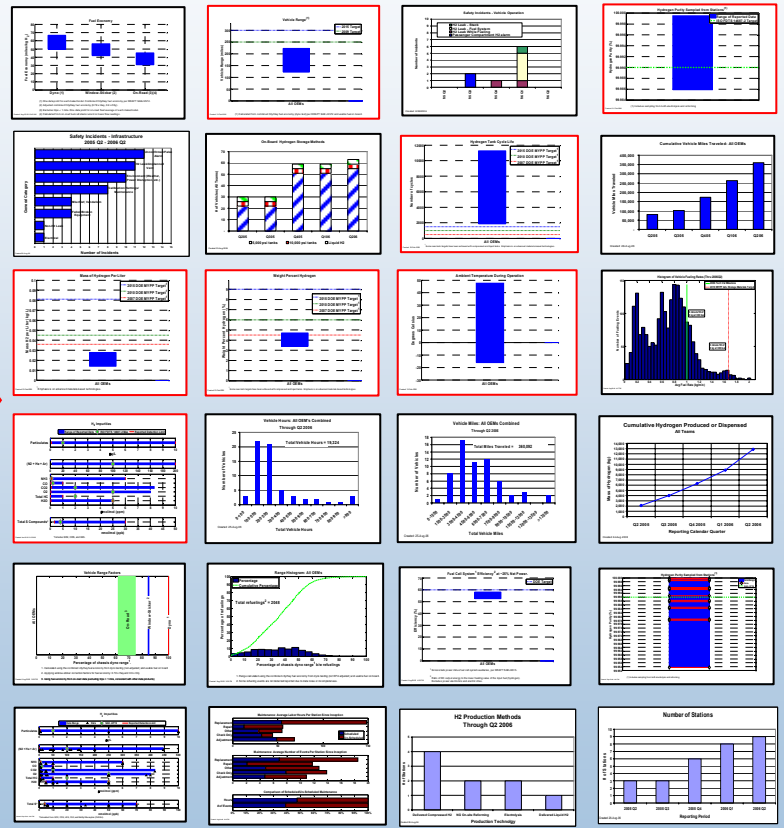
Fuel Cell Seminar
November 15, 2006

All public Learning Demo papers and presentations are available online at http://www.nrel.gov/hydrogen/proj_tech_validation.html

Quantity of Project Results Continues to Increase; Updates Every Six Months

Spring 2006

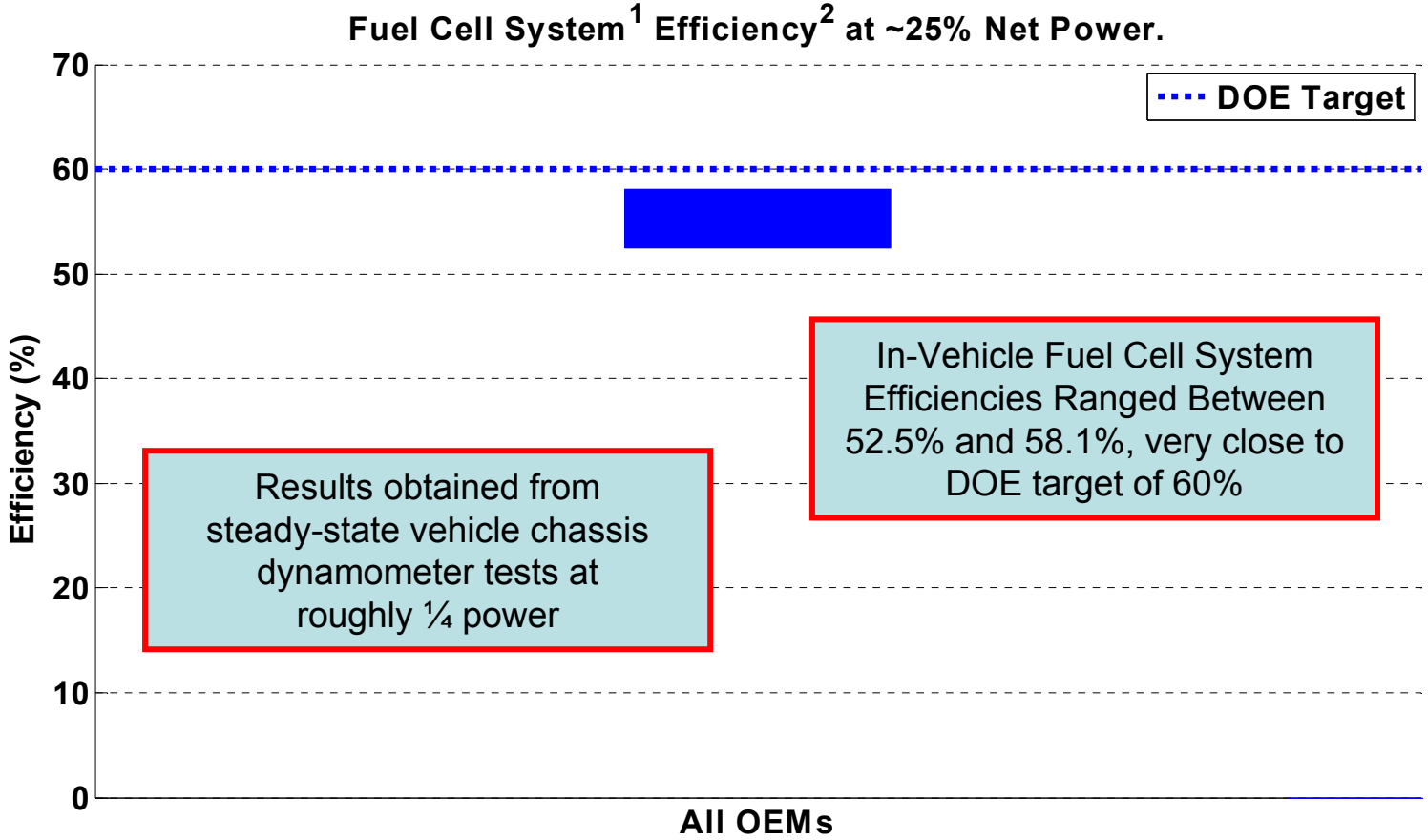
Fall 2006



24 Composite Data Products Have Now Been Published, Including Updating Many of the 16 Published in Spring 2006

RESULTS

Controlled System Tests Verify High Fuel Cell System Conversion Efficiency



[1] Gross stack power minus fuel cell system auxiliaries, per DRAFT SAEJ2615.

[2] Ratio of DC output energy to the lower heating value of the input fuel (hydrogen). Excludes power electronics and electric drive.

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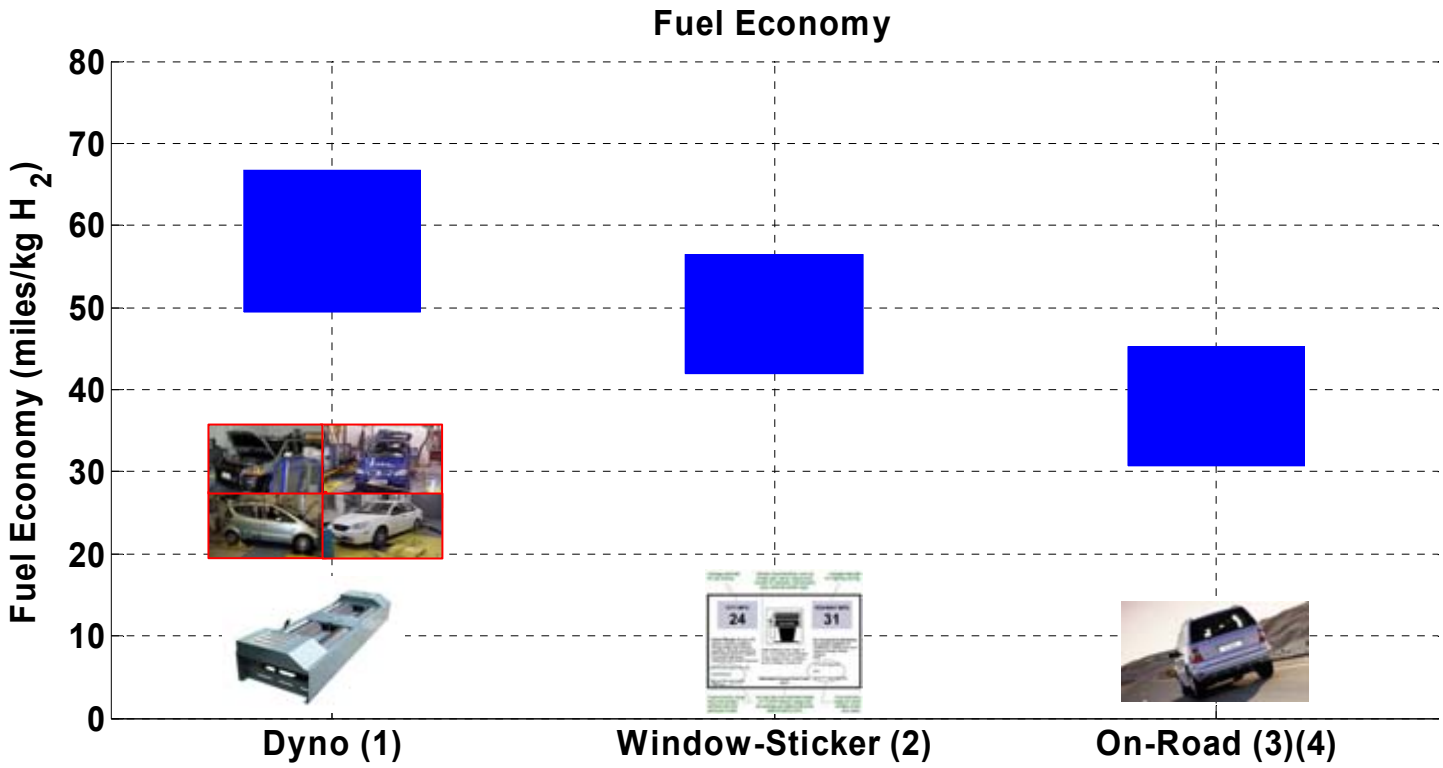
Dynamometer and On-Road Fuel Economy from Learning Demonstration Vehicles



(1) One data point for each make/model. Combined City/Hwy fuel economy per DRAFT SAEJ2572.

(2) Adjusted combined City/Hwy fuel economy (0.78 x Hwy, 0.9 x City).

(3) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.

(4) Calculated from on-road fuel cell stack current or mass flow readings.

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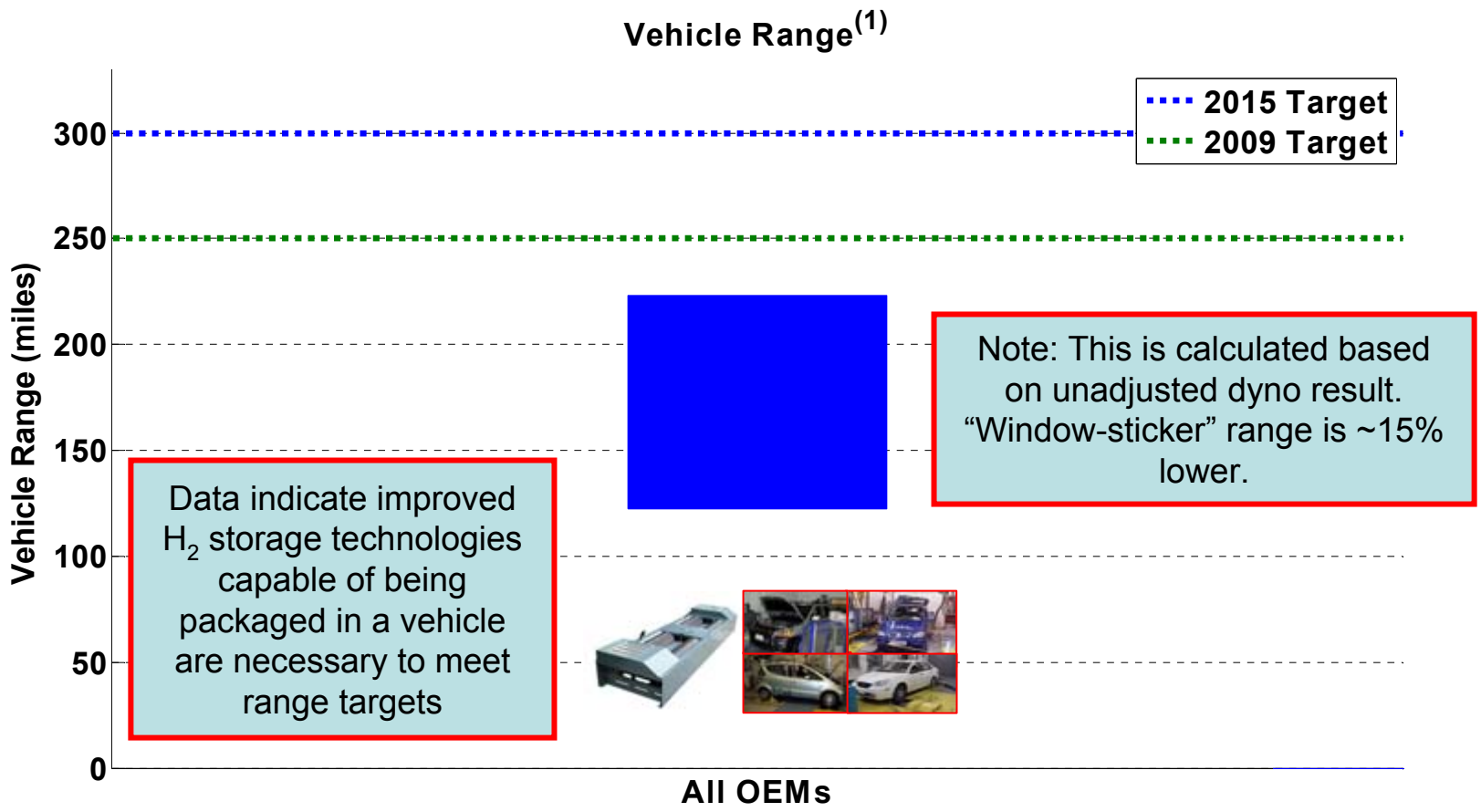
Vehicle Range Based on Dyno Results and Usable H_2 Fuel Stored On-Board



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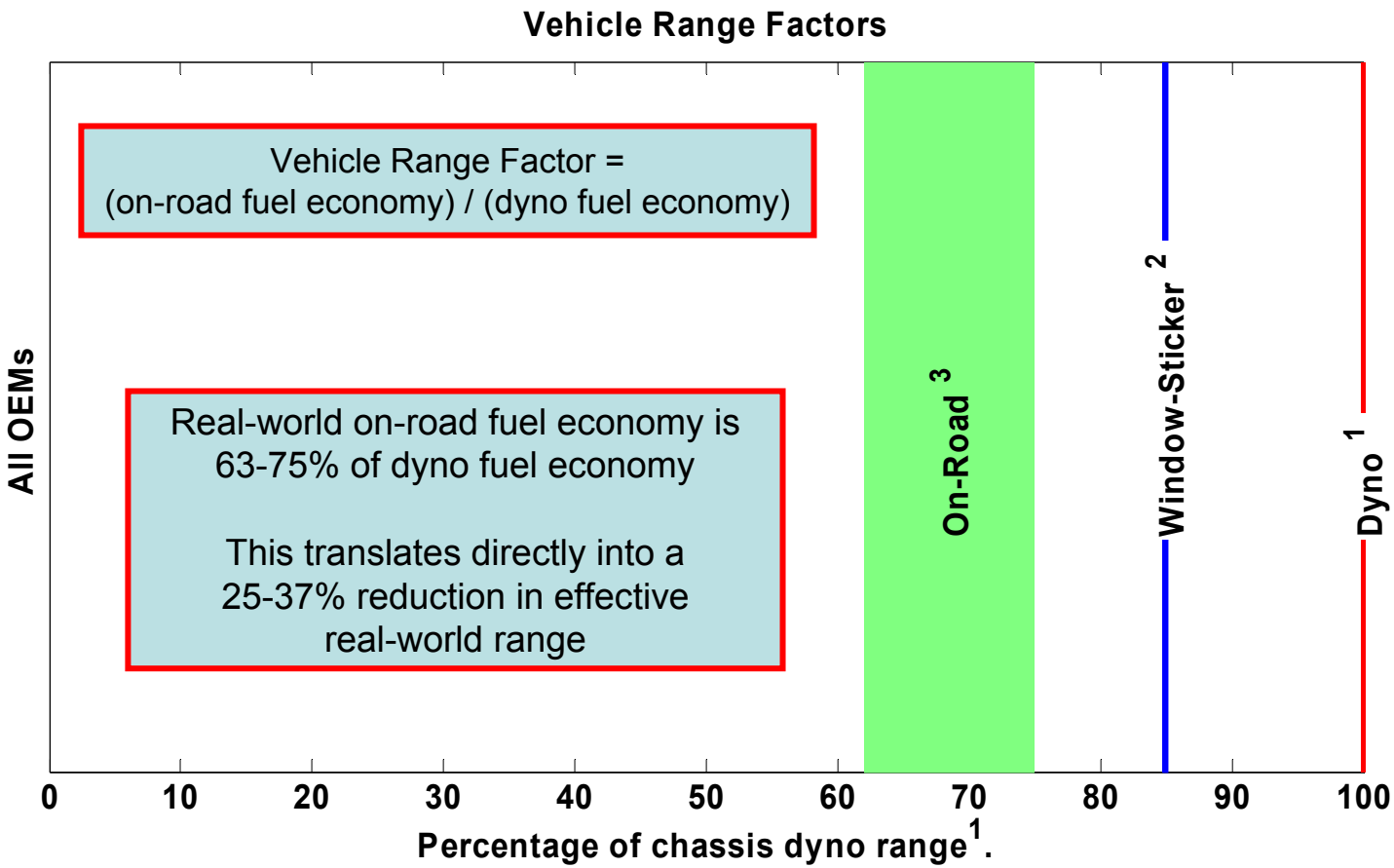
(1) Calculated from combined City/Hwy fuel economy (dyno test) per DRAFT SAE J2572 and usable fuel on board.

Effective Vehicle Range Reduced from Dyno Range by On-Road Fuel Economy



1. Calculated using the combined city/hwy fuel economy from dyno testing (non-adjusted) and usable fuel on board
2. Applying window-sticker correction factors for fuel economy: 0.78 x Hwy and 0.9 x City
3. Using fuel-economy from on-road data (excluding trips > 1 mile, consistent with other data products)

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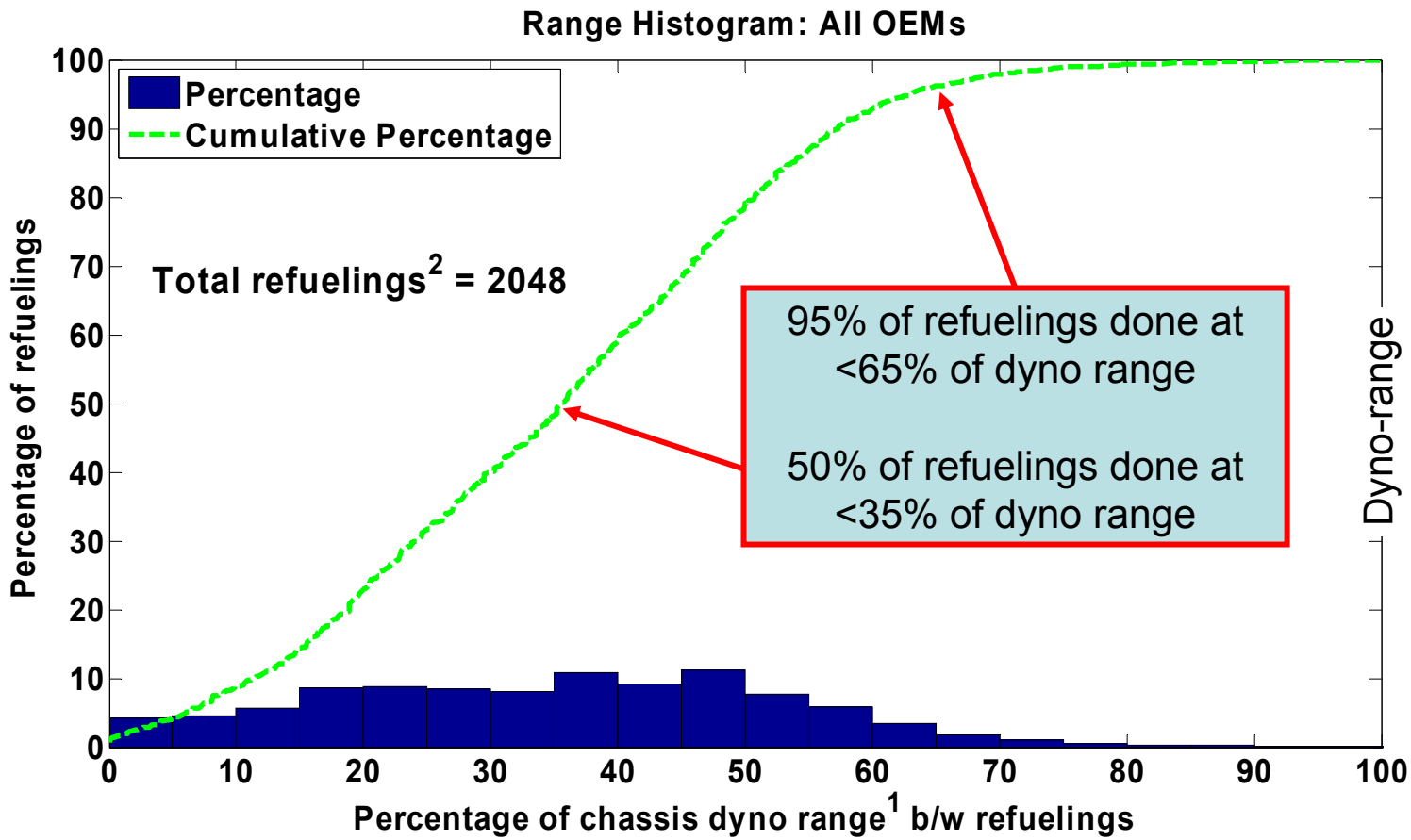
Learning Demo Data Show Actual Refueling Behavior as % of Theoretical



1. Range calculated using the combined city/hwy fuel economy from dyno testing (not EPA adjusted) and usable fuel on board.
2. Some refueling events are not detected/reported due to data noise or incompleteness.

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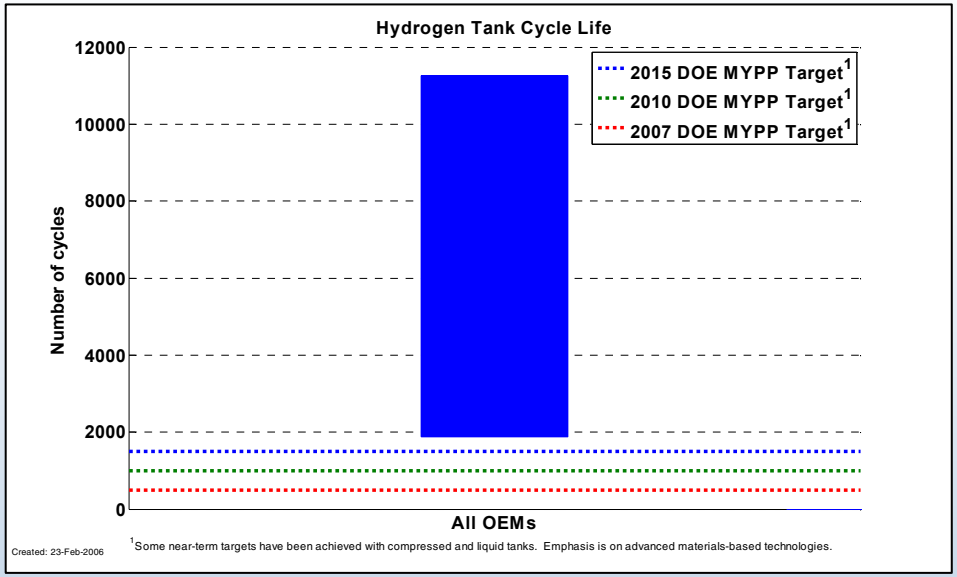
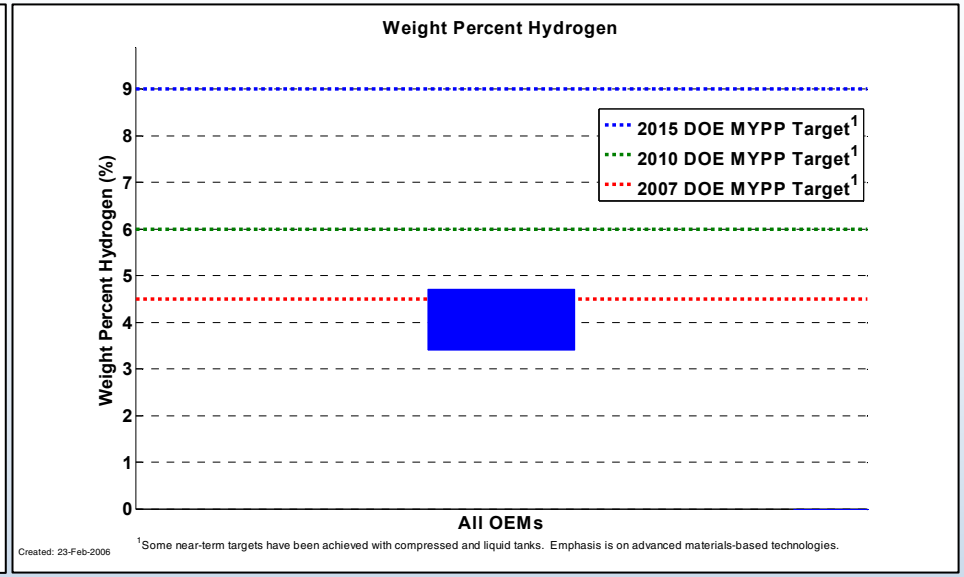
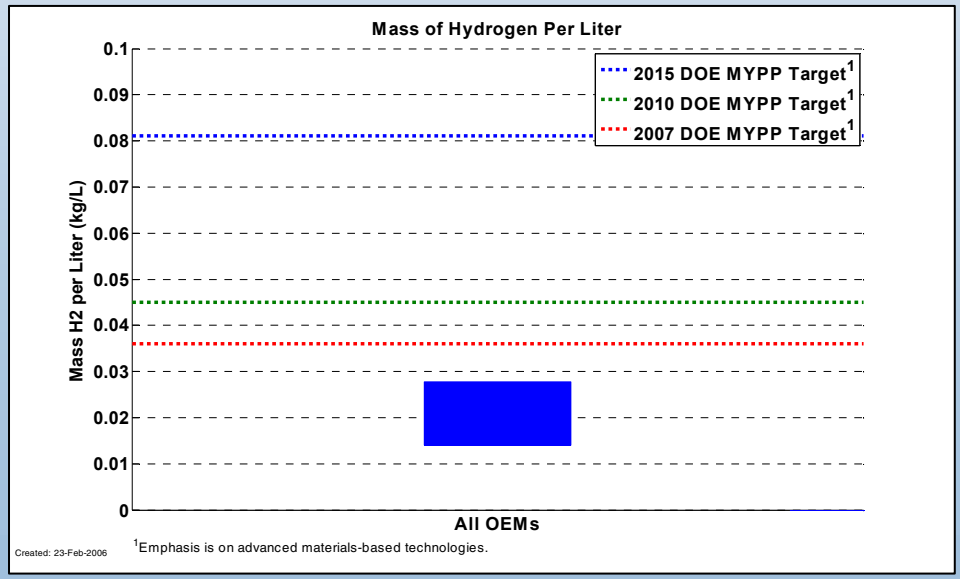
Technical Status of On-Board H_2 Storage Technologies Being Validated

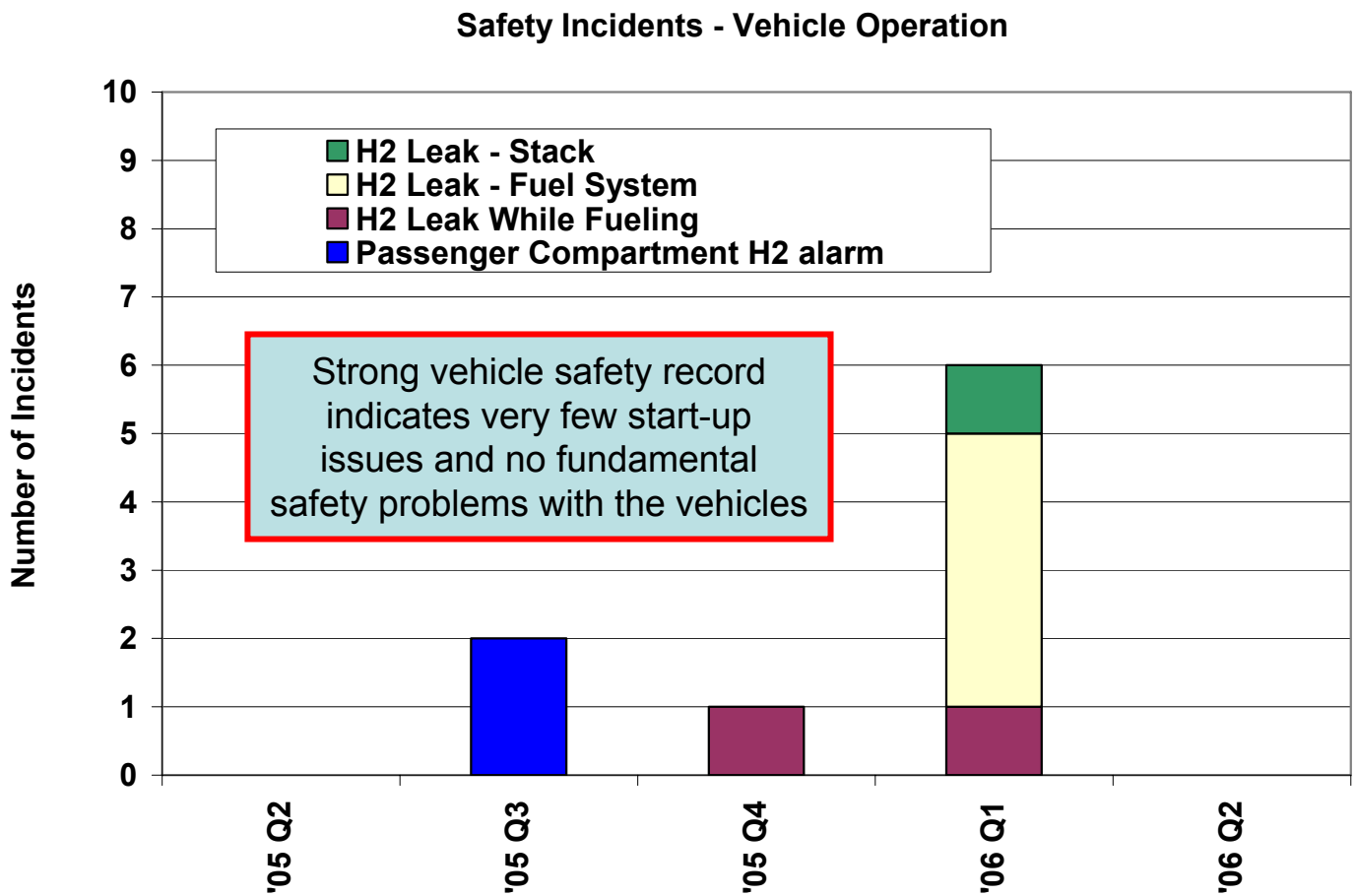






Compressed and liquid H_2 tanks meet durability and short term weight %, but don't meet long-term weight % or volumetric capacity targets for vehicles

Safety Incidents – Vehicles



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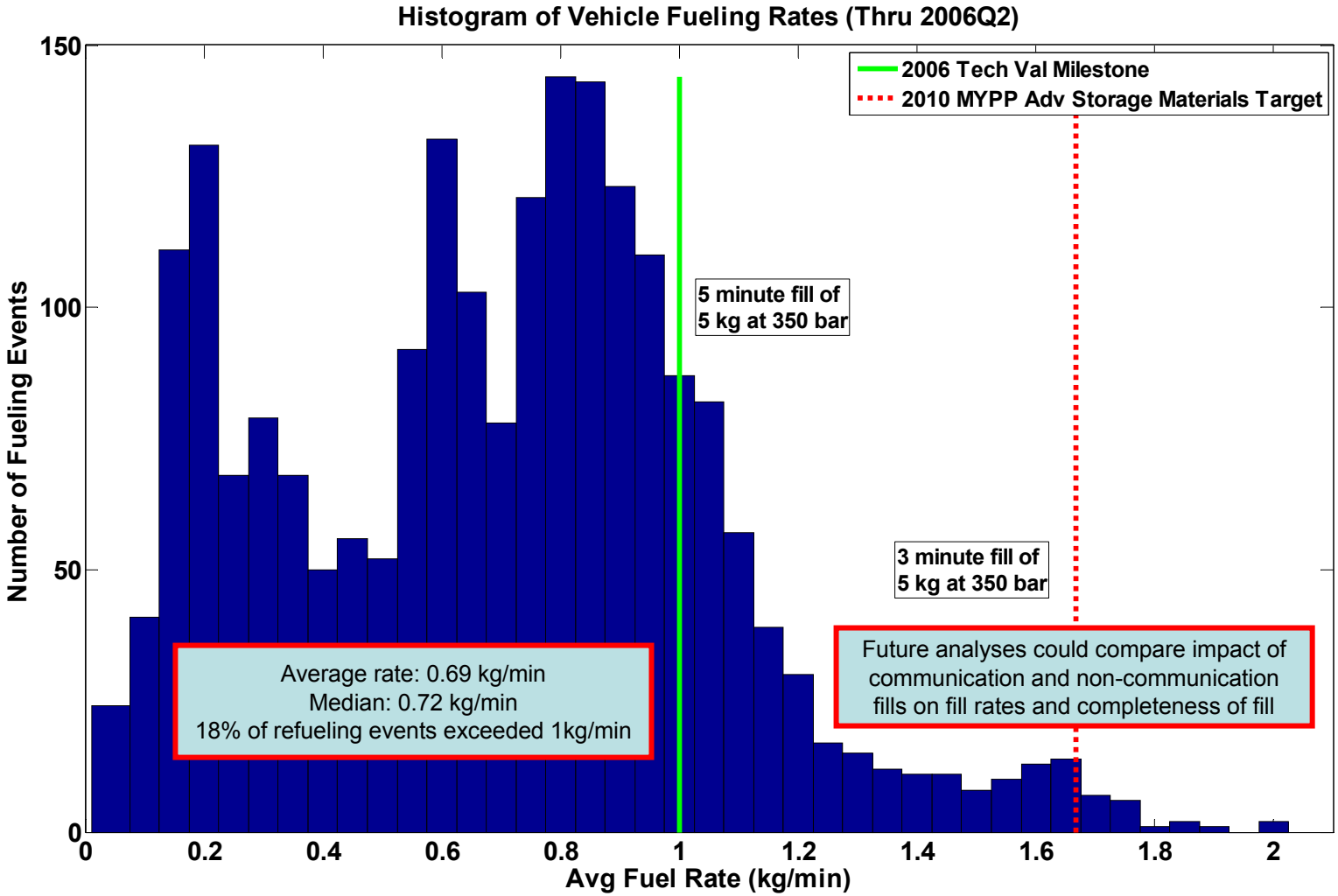
Actual Vehicle Refueling Rates from >2000 Events: Measured by Stations or by Vehicles



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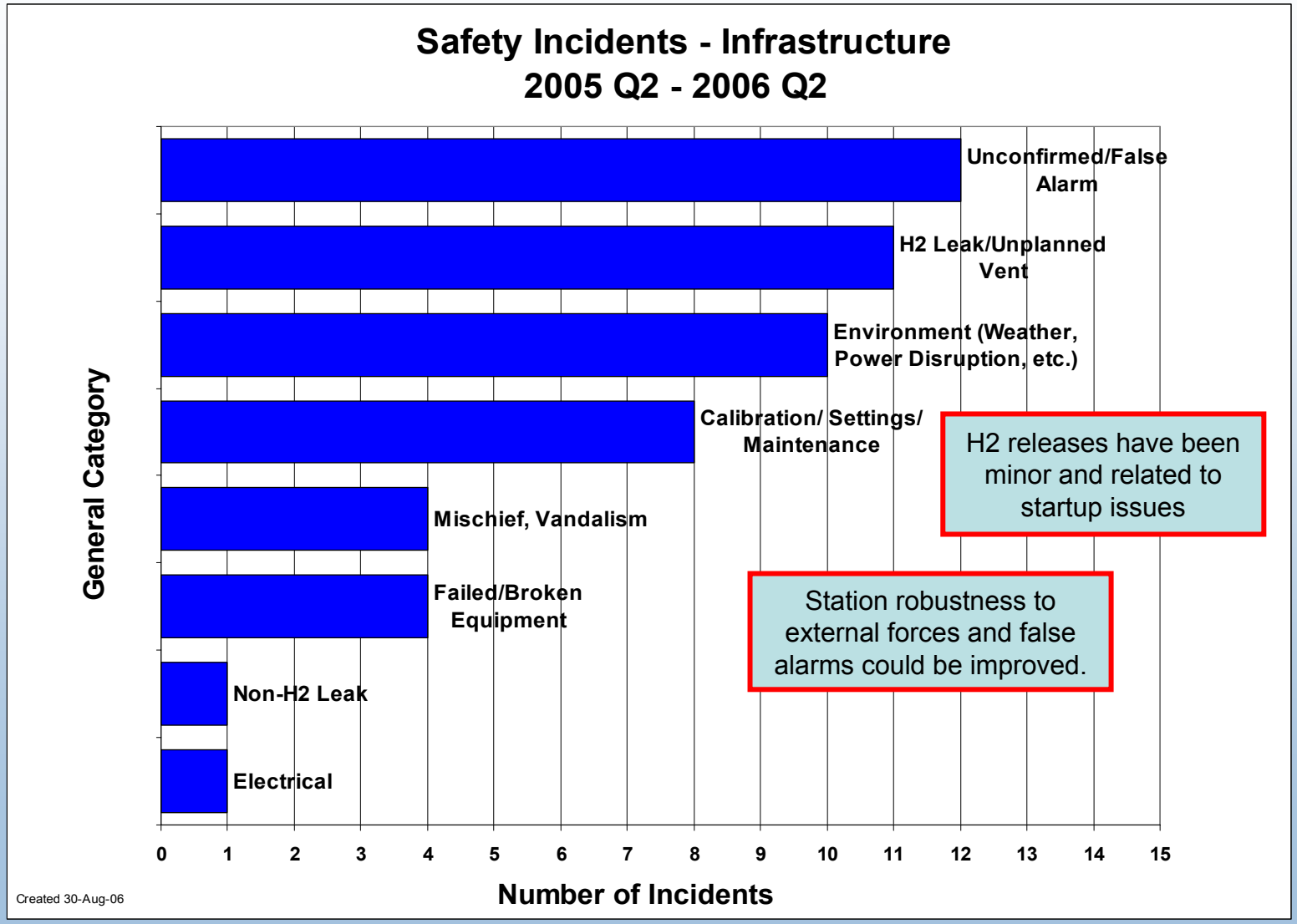
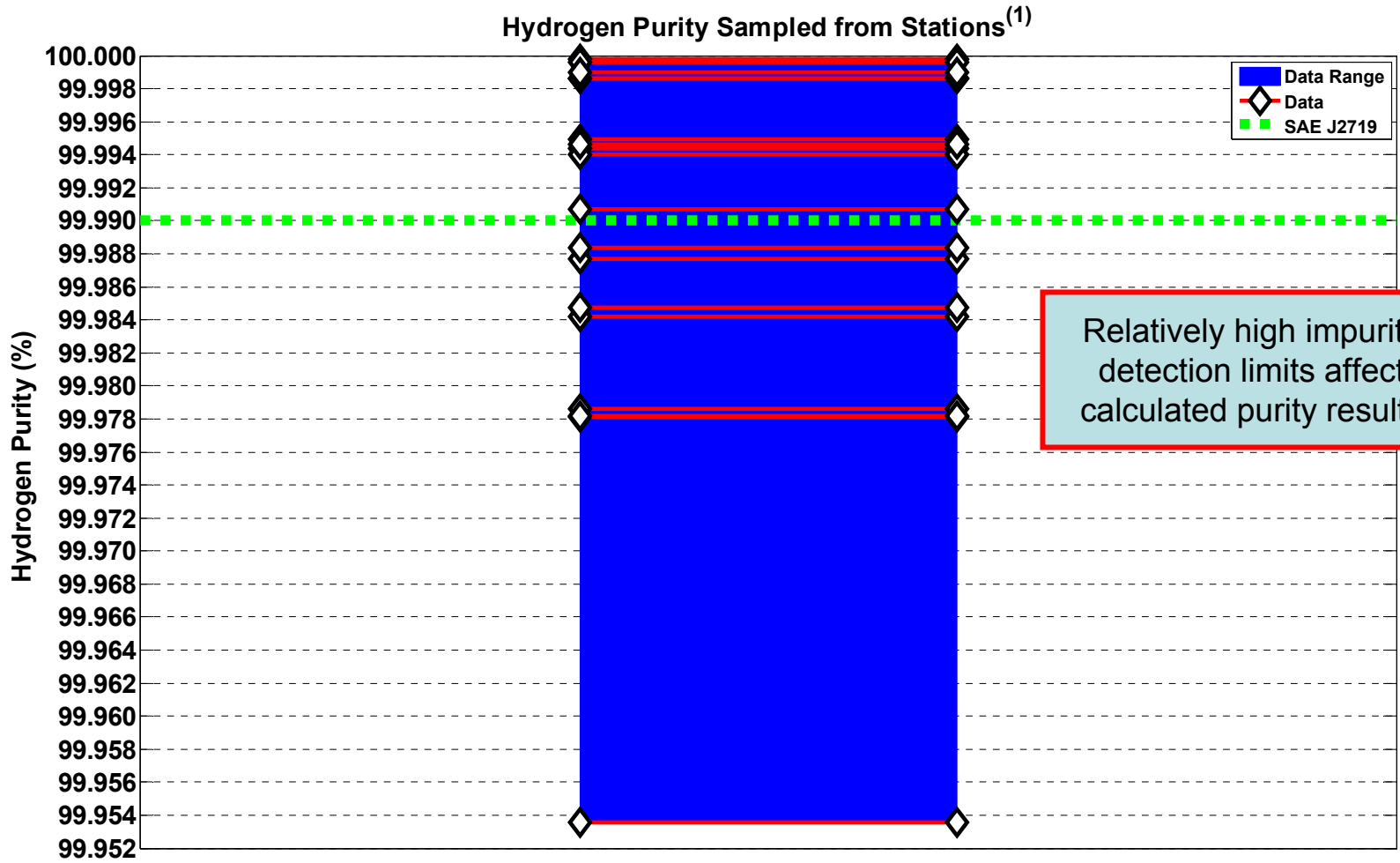
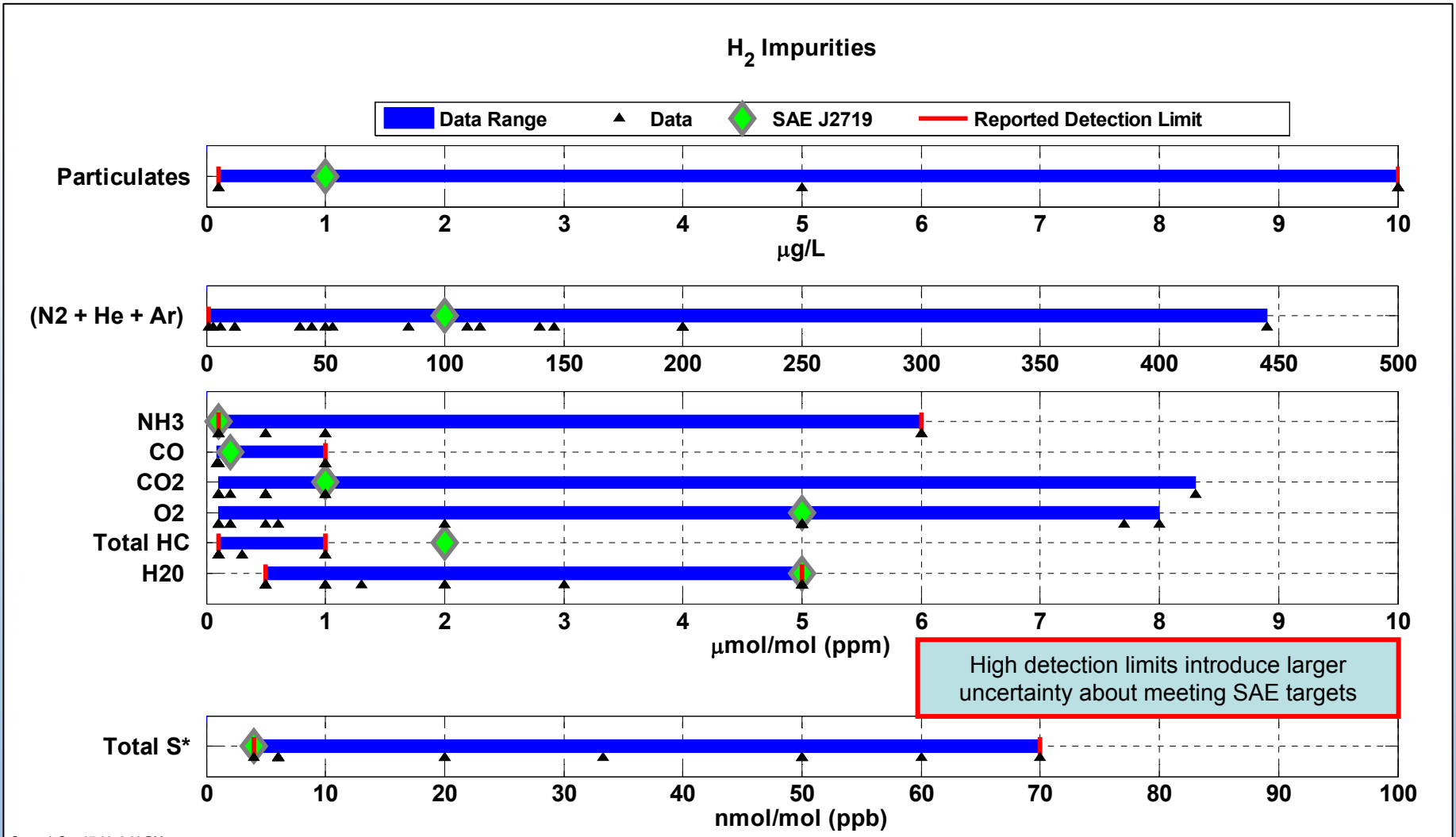
Safety Incidents – Infrastructure



Hydrogen Purity Sampled from Stations Close to Target Majority of the Time



Hydrogen Impurities Sampled from All Stations – Includes On-Site Reformation, Electrolysis, and Delivered H_2



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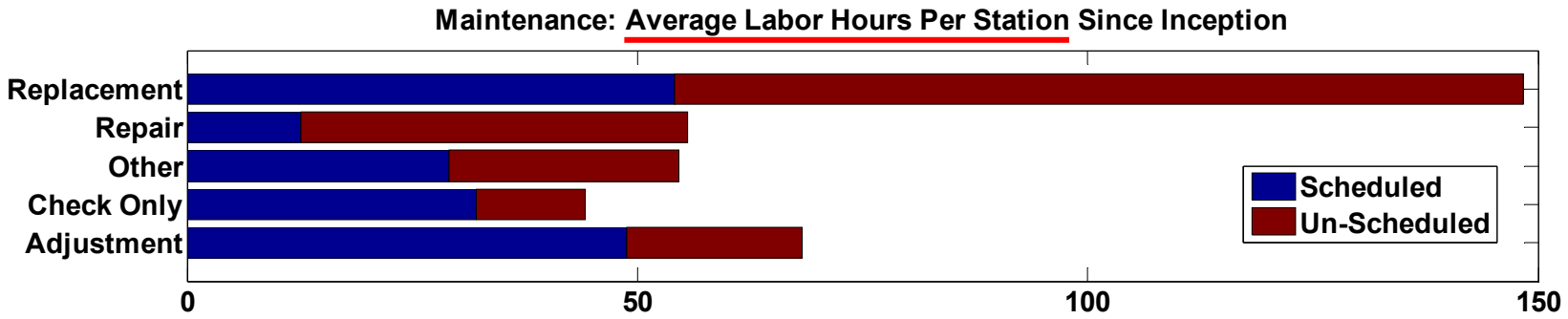
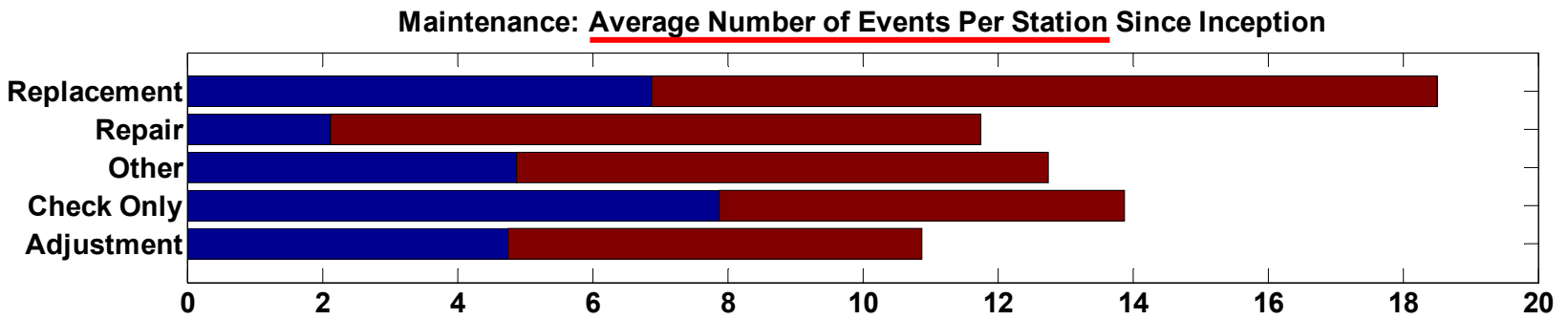
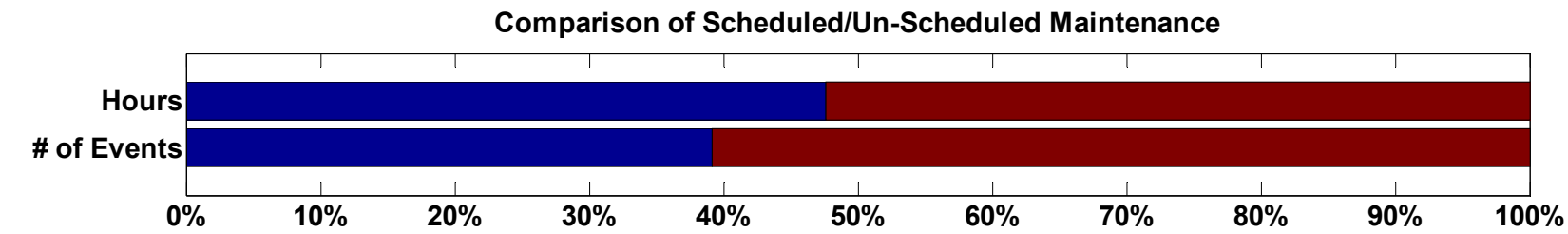
*Calculated from SO2, COS, H2S, CS2, and Methyl Mercaptan (CH3SH).

Unscheduled H2 Refueling Infrastructure Maintenance ~50-60% of Total







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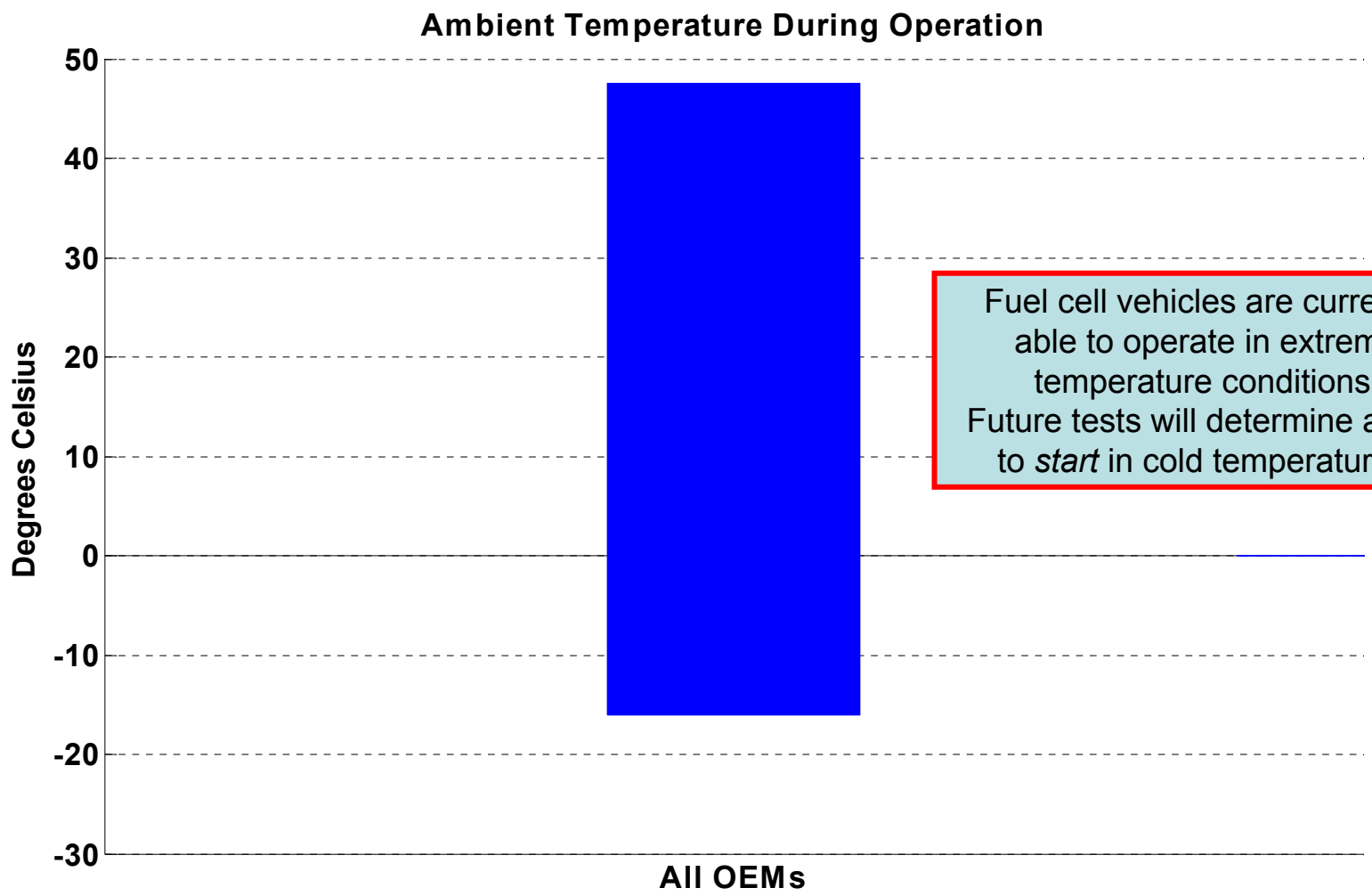
Range of Ambient Temperature During Vehicle Operation



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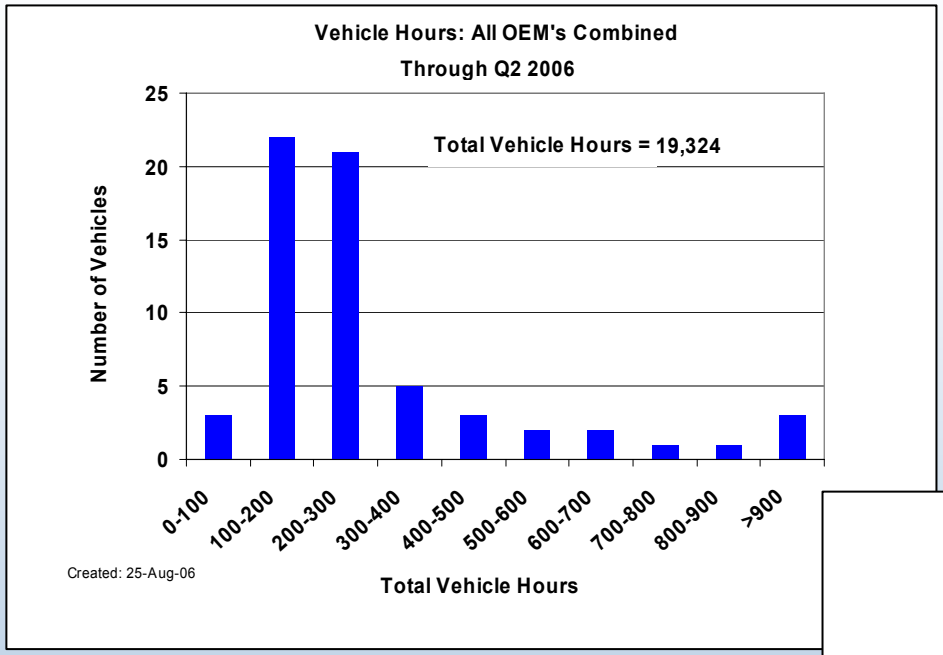
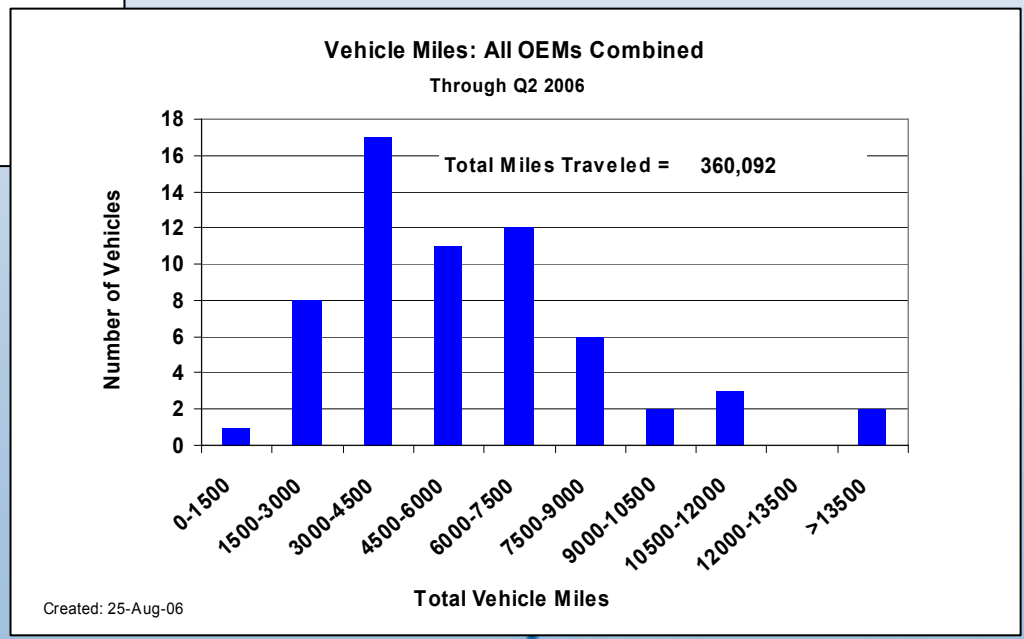
Vehicle Operating Hours and Miles Traveled Distribution

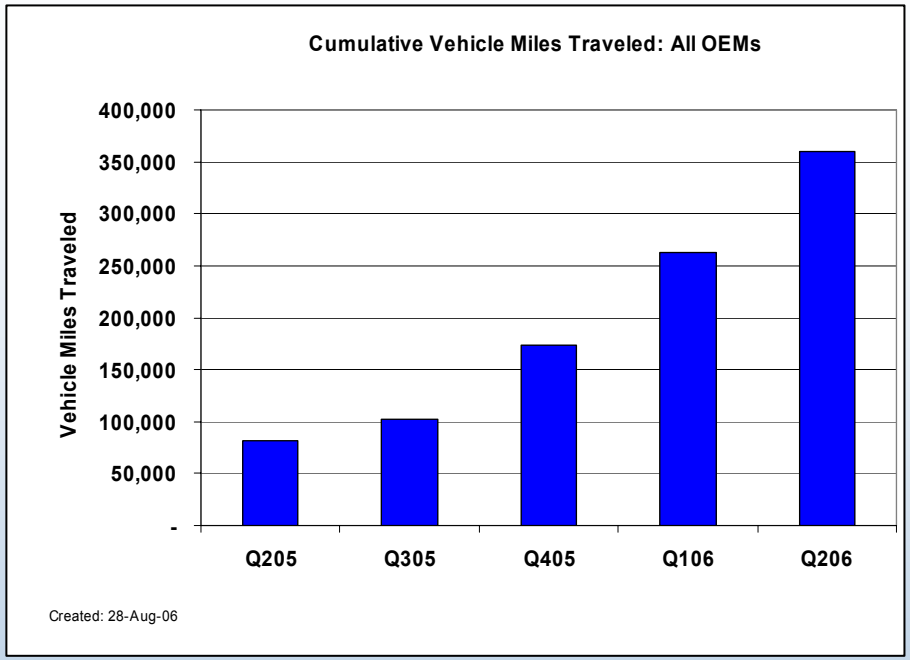


The bulge of operating hours and miles traveled is now shifting to the right.

New Gen 1 vehicles continue to be introduced, but 2nd bulge will appear at left with Gen 2 vehicle introduction.

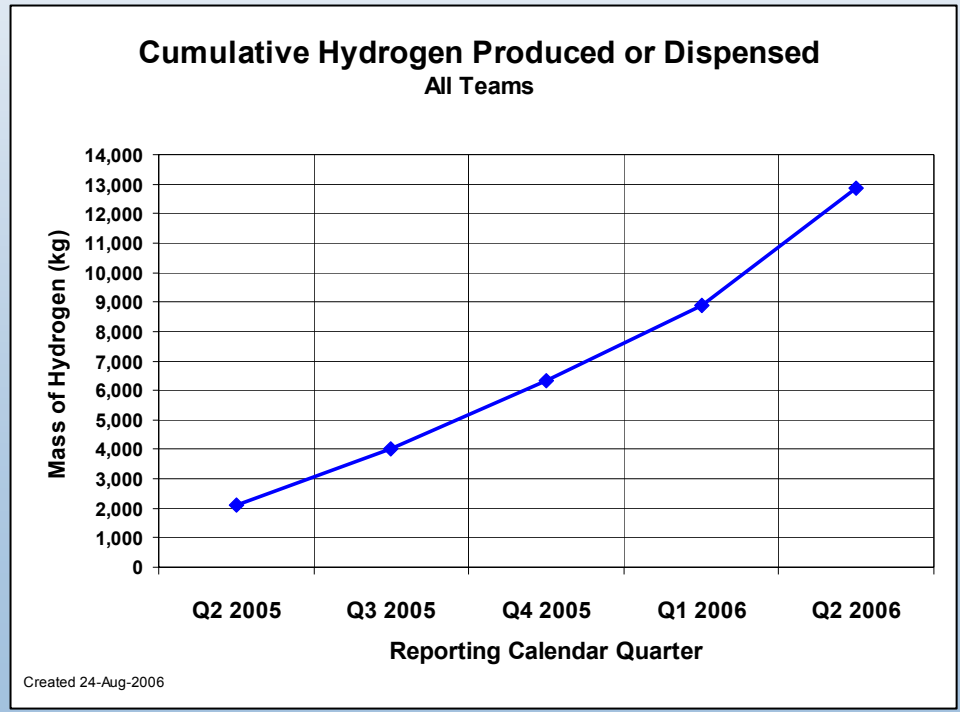


Cumulative Vehicle Miles Traveled and Mass of H_2 Produced or Dispensed

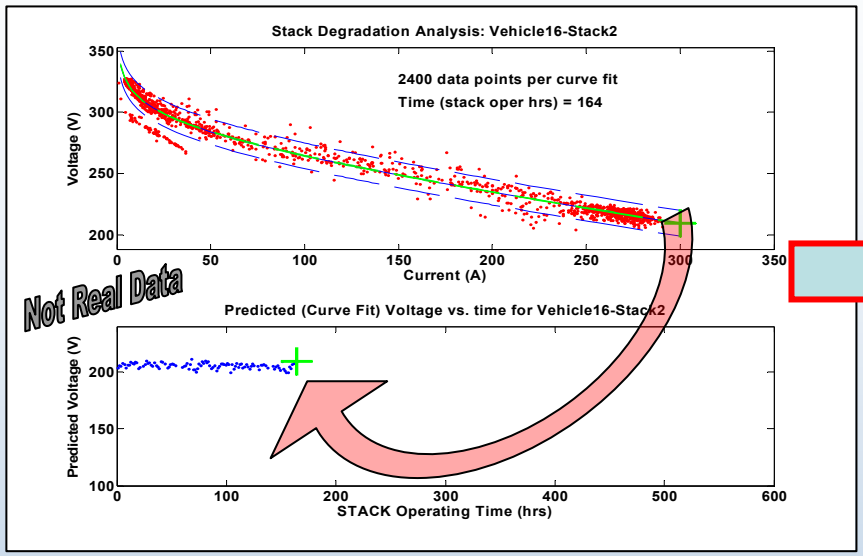


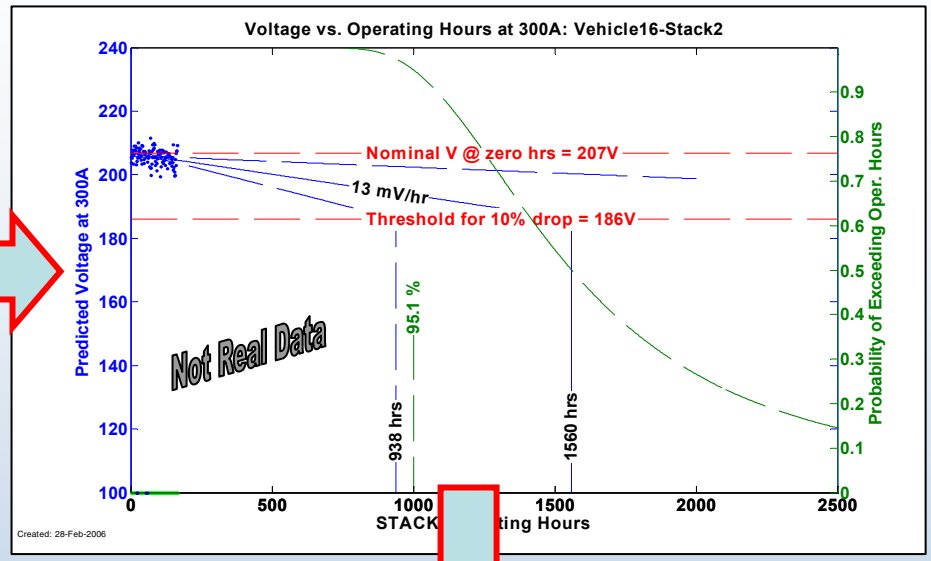
Rate of mileage accumulation increasing as initial fleets approach full Gen 1 vehicle deployment

Current deployment of new H_2 refueling stations for this project is about 50% complete.
Many mobile refuelers will be replaced with on-site generation



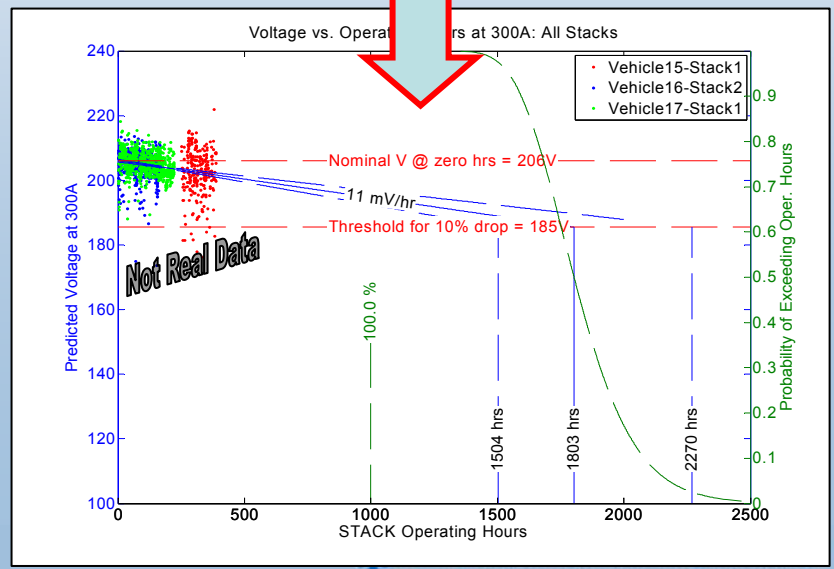
Methodology for Projecting Stack Durability– Results to be Published this Fall





Technique Makes Performance Projection Based on All Available FC Data; Includes Reporting Confidence in Results

Voltage Degradation Analysis Technique Key to Evaluating Data Relative to DOE FC Durability Target in Fall 2006

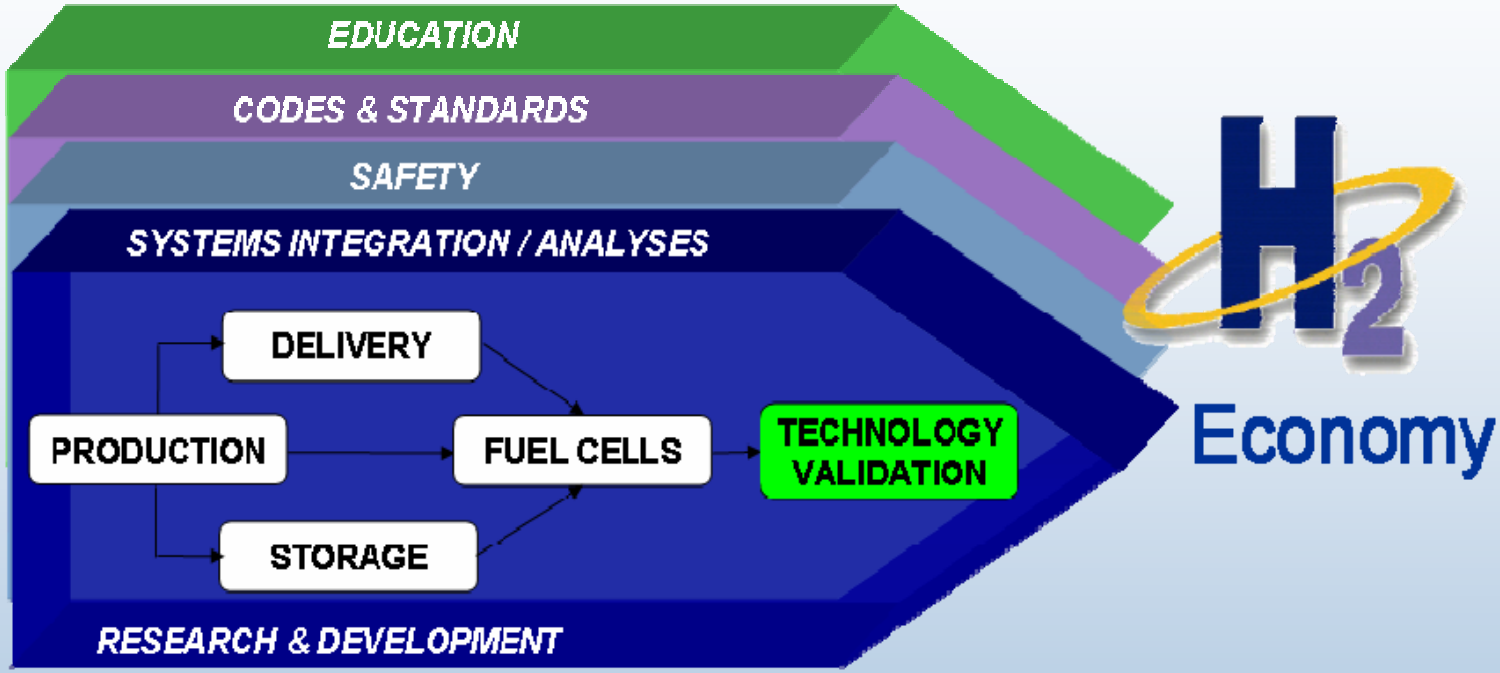


Summary

- First 5-quarters of project completed
  - 63 vehicles now in fleet operation
  - Several new refueling stations opened
  - No major safety problems encountered
  - Total of 24 composite data products published
- Project has identified current technical status relative to program targets
  - Will track improvements from 2nd generation stacks/vehicles introduced mid-way through project
- Future public results will include:
  - 6-month updates to existing composite data products
  - Fuel cell durability* and cold start-up times
  - H_2 production cost and efficiency
  - Other composite data products created based on insights learned

*To be presented at EVS-22 and Fuel Cell Seminar

Questions and Discussion



Contact: Keith Wipke, National Renewable Energy Lab
303.275.4451 keith_wipke@nrel.gov

All papers and presentations are available online at
http://www.nrel.gov/hydrogen/proj_tech_validation.html